Spectrum of Engineering Sciences
ISSN (e) 3007-3138 (p) 3007-312X
Volume 4, Issue 2, 2026

COMPARATIVE ANALYSIS OF ARCHIMEDEAN MICRO HYDRO SCREW TURBINE USING ANALYTICAL METHODS

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DOI: https://doi.org/10.5281/zenodo.18680106

Keywords
Archimedean Screw Turbine, Modified Turbine, Turbine Length, Analytical Methods etc.

Article History
Received: 15 December 2025
Accepted: 30 January 2026
Published: 14 February 2026

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Abstract

This study presents a comparative analysis between Archimedean screw turbine design and a modified turbine design. The research investigates the impact of two critical design parameters: turbine length and number of blades, on the performance of the turbine. This study utilizes a turbine length of 0.96 m and 3 blades, whereas the modified design features an enhanced turbine length of 1.524 m and 7 blades, aiming to improve energy extraction efficiency and power output. Analytical methods were employed to evaluate key performance metrics, including hydraulic power, mechanical power, electrical power, and efficiency. The analysis was conducted under similar flow rates (0.05, 0.11, 0.17 m^3/s) and head conditions 4.2. The results demonstrate that the modified turbine achieves significantly higher power output due to the extended interaction of water with the turbine and improved water capture efficiency. For instance, at a flow rate of 0.11m^3/s the hydraulic power increased from 2855.6 to 4532.2 and the electrical power increased from 747.7 to 2773.7. The study underscores the importance of turbine design modifications in optimizing power output for low-head hydroelectric applications and highlights the potential of Archimedean screw turbines in meeting rural energy demands. This study contributes to the body of knowledge on small-scale hydroelectric systems, offering insights into design improvements for enhanced energy efficiency and sustainability in micro-hydro applications.

1. INTRODUCTION

1.1 Background of the Study

The community has a significant and growing annual demand for electrical energy. In many countries, the electrical energy produced by power plants has been professionally managed, starting from the generation, distribution, and marketing of this energy to the public. Regarding the distribution of electrical energy: not all places, particularly the most remote and isolated ones, have access to electricity. It can transform several energy sources into electrical energy, even in some isolated places. An instance of a potential electrical energy source is the river's flow, which flows through this isolated region.

Micro-hydropower plants may be an option for the supply of electricity in places with these circumstances. Various kinds of micro-hydroelectric power plants exist. There are benefits and drawbacks to each of these kinds. The Archimedes screw turbine power plant is one kind of power plant. Among the benefits of the Archimedes screw turbine is its suitability for use in rivers with moderate current speeds, doesn't harm the surrounding environment doesn't interfere with fish life in the river, and so on (Fig. 1.1).

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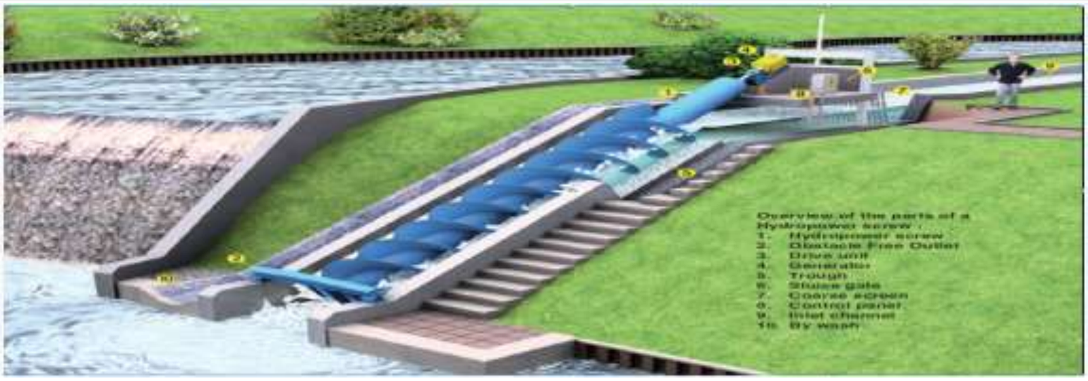


Figure 0.1: Diagram of Archimedes Turbine

Generating energy from traditional ways is a matter of concern as it is affecting the ecosystem and will be disastrous for the mankind in a longer period. The future is to generate green energy by utilizing traditional knowledge. Archimedes screw which has been used by mankind from centuries is the best way out. Archimedes screw turbine is a new concept which emerged 20 years back for being used as a generator to generate electricity (Lashofer2012). Archimedes screw turbine shows its maximum efficiency at low heads and that is why it can be used at the places where the other turbines cannot be used. Moreover, the Archimedes screw turbine is fish friendly and does not affect the ecosystem. While we consider the application of Archimedes in hilly region of western Himalayan region, this could be a game changer as it can generate electricity to fulfill the energy needs of people living in rural areas by utilizing locally available watermills available in these terrains.

The screw turbine designed by Archimedes has been thoroughly investigated both theoretically and experimentally. The study's findings suggest that the Archimedes screw turbine operates well. Additionally, several Archimedes screw turbine analyses and designs have been made to improve and maximize turbine performance. To create a sufficient supply of energy, the benefits of the Archimedes screw turbine which can be employed in rivers that aren't too heavy in isolated places can be coupled with solar energy. Further examination of the attributes of the Archimedes screw turbine on different elements has moreover been completed. To act as an illustration of exploration on the impact of the degree of filling water (liquid) in the turbine on the qualities and execution of the turbine, research on the impact of the progression of water (liquid) going through the turbine on the attributes and execution of the turbine, research on the impact of the slant and number of turbines cutting edges on turbine qualities and execution.

1.1.1 Motivation

The pressing need for environmentally friendly and sustainable energy sources is what inspired the Archimedes Screw Hydro Power Turbine. This technology offers an effective way to harness the power of water in a way that is consistent with environmental preservation as the world moves toward renewable energy to fight climate change. The Archimedes screw can be used in rivers and streams that were previously unexplored for energy production because, in contrast to conventional hydroelectric turbines, it functions well in low-head water conditions. It is also a harmonious option for green energy projects because of its environmentally conscious and fish-friendly design, which guarantees little disturbance to aquatic ecosystems.

In addition, this turbine meets practical energy needs and socioeconomic ones. It is an affordable solution for communities, particularly in rural or developing areas, because of its straightforward, sturdy design, which guarantees low maintenance and long-term durability. It promotes energy independence and lessens reliance on massive power grids by permitting localized energy generation. This modern adaptation, which draws inspiration from Archimedes' engineering prowess, combines historical inventiveness with modern needs to demonstrate how cutting-edge, small-scale technologies can support global sustainability objectives.

1.2 Problem Statement

Pakistan's rivers have a lot of unrealized hydropower potential, but one of the biggest obstacles to its development is the absence of effective low-head turbine technology. Due to their low efficiency of about 10%, current low-head turbines produce little energy and deter investment in small-scale hydropower projects. Pakistan's continued reliance on fossil fuels exacerbates its economic and environmental problems. Hydropower projects in the area will not be financially feasible without optimized turbine blade designs and increased efficiency, which will restrict the production of sustainable energy and rural electrification. The study's objective is to investigate and create effective low-head turbine options for the river in order to boost energy output and aid Pakistan's renewable energy objectives.

1.3 Research GAP

There is a gap regarding the installation, power and efficiency optimization of Archimedes screw turbines, which are specifically designed for the Pakistani river. Numerous studies have examined the screw turbine's performance, but few have focused on its ultra-low head applications in arid or semi-arid areas. These areas also have sediment-concentrated water and irregular water flow rates. Our study's novelty lies in using the analytical method to change the pitch, material, and geometry in order to significantly reduce the effects of sediment-concentrated water on the turbine—a difficult condition. This localized innovation has helped close the gap in our nation's less developed areas. Analytical models for energy optimization were not investigated in earlier research, which relied on CFD (ANSYS) to maximize efficiency. However, accuracy is still limited, and further process improvement is required.

1.4 Objective of the Study

This study's goal is to specifically adapt and enhance an Archimedean Micro Hydro Screw Turbine for effective power generation in low-head water conditions. Through the use of analytical techniques, the project aims to improve energy extraction efficiency and boost power output by adjusting important design parameters like turbine length and blade count.

- To optimize Archimedes screw turbine design by focusing on screw geometry, blade count, and rpm to improve efficiency and performance.
- To calculate efficiency and power output of the optimized Archimedes screw turbine using analytical methods.
- To build and test an optimized Archimedes screw turbine prototype.

1.5 Scope and Limitation

The project focuses on optimizing the design and performance of the Archimedean Micro Hydro Screw Turbine for efficient power generation in low-head water conditions. The study includes:

1) Increasing turbine length and the number of blades to improve energy extraction.
2) Evaluating key performance parameters such as hydraulic, mechanical, and electrical power output.
3) Constructing a working model of the modified screw turbine and testing its efficiency.

2. RESEARCH METHODOLOGY

2.1 Introduction

The approach used in this study is described in this chapter, which also provides information on the research design, participants, sampling strategies, tools, data gathering techniques, and data analysis processes used to meet the goals of the study. The method is designed to guarantee a thorough and methodical approach to the gathering and examination of data. This study's emphasis is on the Archimedean Micro Screw Turbine; comparisons are made between the prototype used in this work and those found in current literature. Considering different factors including head, flow rate, number of blades, turbine length, and others, this part offers a thorough knowledge of the method employed to examine the efficacy and efficiency of the turbine model.

2.2 Research Design

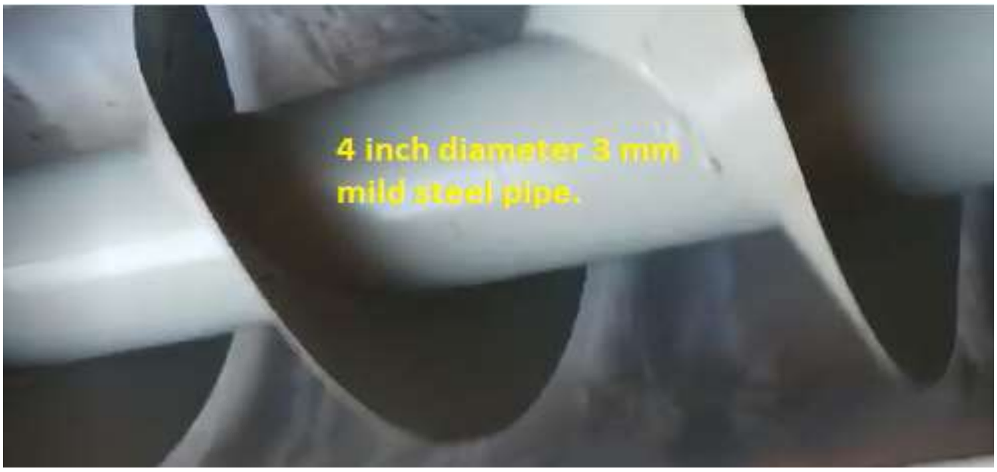
This work's research design is experimental and comparative. To enable direct measurement and analysis of the hydraulic, mechanical, and electrical power outputs produced by the Archimedean Micro Screw Turbine, the experimental design was chosen. Among other things, the study emphasizes assessing these outputs depending on particular criteria including head (H), flow rate (Q), and number of blades. The comparative part of the research is a comparison of the findings of the present project with those of prior studies located in the literature. This method lets one assess the power generation capacity, performance, and efficiency of the prototype in relation to current models.

2.3 Materials List and Description

Table 2.1: Materials List & Description

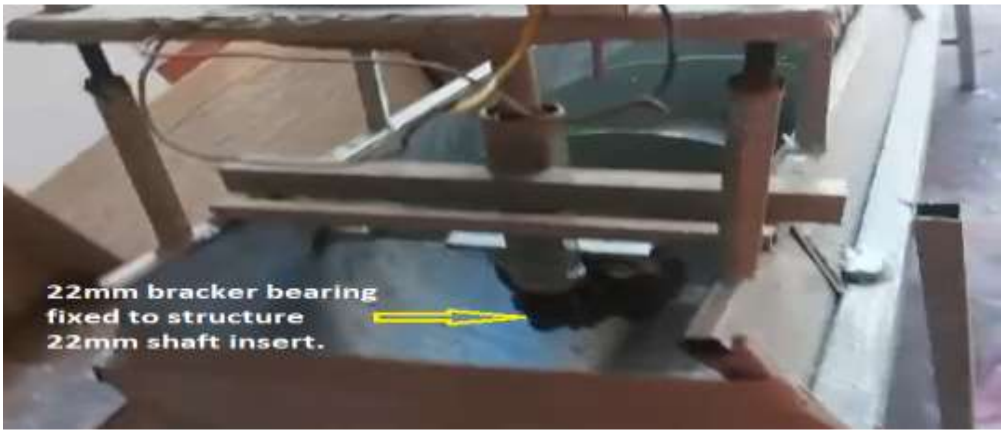
Materials List	Description
Mild Steel Pipe	The center of the screw is a 4-inch, 3mm mild steel pipe, 65 inches long. It has a 22mm shaft coming out from both ends to hold the pipe in position, rotating inside bearing brackets.
Spiral Rings	Made of 1.8mm plate welded to the pipe. The external diameter is 11 inches, and the internal is 4.2 inches. There are 6 full and half spiral rings welded to the pipe at an 18-degree spiral and 25-degree inward slant for better water grip and power generation.
Bracket Bearings	The pivot point of the screw is inside the bracket bearings at each extreme end. These bearings support the weight of the screw and the water, which can be up to 30 kg, with the bearings able to support 100 kg of load, exceeding the flow rate power.
Structure	The structure is made of RHS (25mm x 25mm), 6.2 feet long, and 15 inches wide. It is inclined at 35 degrees to allow water to flow easily. The structure is covered with a GI sheet, providing a 12-inch diameter curve. A 12-15mm gap between the pipe and sheet allows water flow.
NDFEB Magnets	Neodymium magnets, powerful and used in Axial Flux alternators, offer 10-15 times the strength of conventional magnets. They are made of iron and boron and are grade 52, contributing to denser magnetic flux for higher power output compared to radial flux alternators.
Fiberglass Resin	Used in the stator construction to hold the coil assembly, fiberglass has high mechanical and thermal properties, is cost-effective, protects against moisture, and is water-resistant. It is primarily a 2-part epoxy resin that provides insulation and resistance to thermal and stress factors.
Enamel Coil for Winding	The stator of the Axial Flux alternator has 7 coils made of 22 SWG enamel-coated copper wire, each with 250 winds. The coils produce up to 4 amperes at maximum running capacity.
Full Wave Bridge Rectifier	The full wave bridge rectifier converts AC to DC power, using four diodes in a Wheatstone bridge arrangement. It provides a consistent power supply to the DC loads without voltage drops, unlike single diode rectifiers that reduce power output and cause voltage drops.
Axial Flux	An Axial Flux alternator uses a disc-like structure with NDFEB magnets, producing a dense magnetic flux parallel to the axis of rotation. It is efficient, compact, and avoids cogging or stiffness due to the absence of a core. It is ideal for generating power from low RPMs.
Radial Flux	Radial Flux alternators have a stator and rotor arrangement perpendicular to each other. In contrast, the Axial Flux alternator is coplanar, offering a better power-to-weight ratio, reducing weight, and saving space.
Axial Flux	The Axial Flux alternator for this project consists of 7 magnets on opposite

Alternator Fabrication	rotor plates and 7 stator coils placed in between. The air gap is approximately 1.2mm. The coils are made with 22 SWG enamel wire and are embedded in fiberglass, generating 12 volts AC at 180 RPM.
Power Generation in Axial Flux	The Axial Flux alternator generates more power at lower RPMs due to denser magnetic flux lines. It is more efficient in generating power from rotational motion at lower speeds compared to traditional radial flux alternators. It outputs a sine wave AC which is converted to DC via a full-wave bridge rectifier.



Mild Steel Pipe

Spiral Welded Pipe

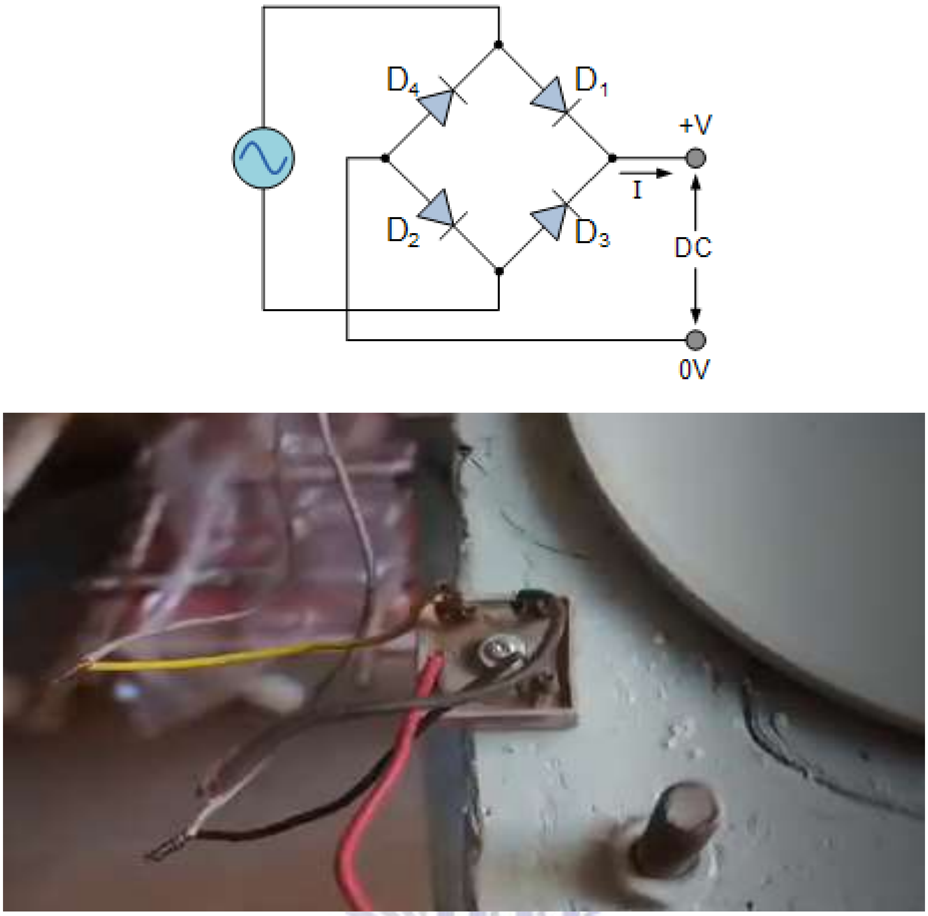


Bracket Bearing

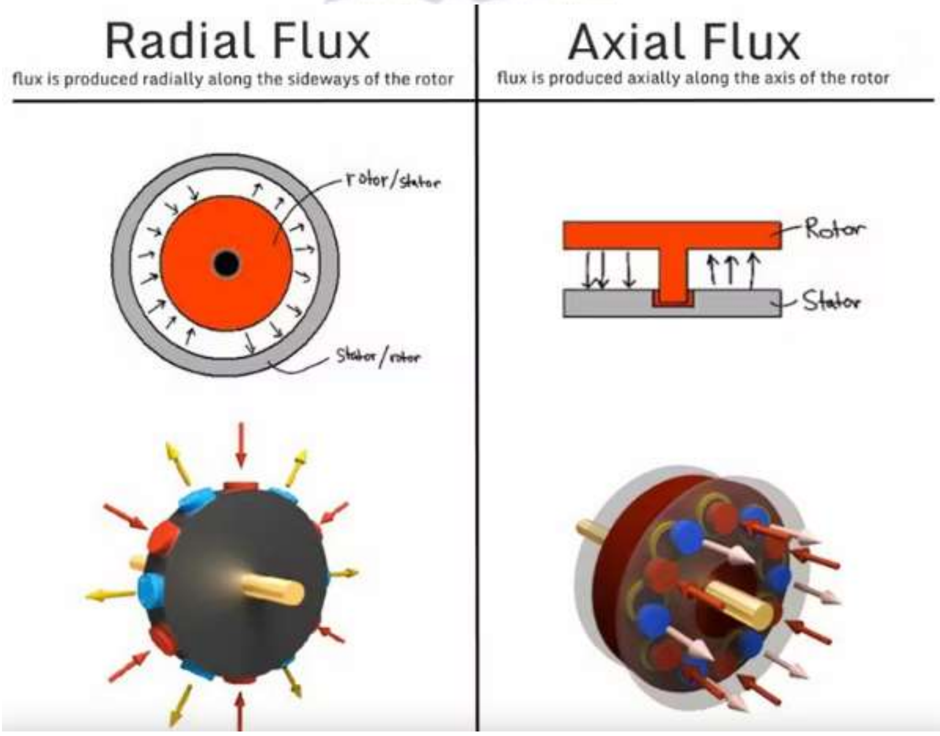
Structure Of System

Stator Cast in Fiberglass

Coils for Stator



Full Wave Bridge Rectifier



Radial and Axial Flux

Person Rotating the Alternator by Hand

2.4 Prototype Dimensions

The Archimedean micro screw turbine prototype developed for this research is designed with the following dimensions, as outlined in Table 3.2. These dimensions are compared with the dimensions of similar studies found in the literature. The parameters include the head, flow rate, turbine blade count, turbine length, radius measurements, and efficiency metrics, as shown below:

Table 2.2: Prototype Dimensions

Parameters	Dimensions of Our FYP	Dimension of Study with the Literature Review
Head (H)	4.2 m	1.65 m - 6.5 m (average 4.2 m)
Flow rate (Q)	0.05, 0.11, 0.17 m^3/s	0.05, 0.11, 0.17 m^3/s
Number of blades (N)	7	3
Turbine length (L)	1.524 m (5 feet)	0.96 m
Distance between gaps (S)	24 cm (0.24 m)	12 cm (0.12 m)
Outer radius (Ro)	12 cm (0.24 m)	42 cm (0.42 m)
Inner radius (Ri)	3 cm (0.03 m)	21 cm (0.21 m)
Resistance (R)	1.8 Ω	2.14 Ω (varies)
RPM	100, 150, 200, 250, 300, 350	100, 150, 200
Efficiency (η)	72%	72%

2.5 Calculation and Formulas

2.5.1 Hydraulic Power Calculation

Hydraulic power ($P_{hydraulic}$) is calculated using:

$$P_{hydraulic} = \rho \times g \times Q \times H \text{ .... (1)}$$

Where ρ = 1000 kg/m^3, g = 9.81 m/s^2 (gravitational acceleration), H = 4.2 m (head) and Q = is the flow rate.

For different flow rates, hydraulic power is calculated as follows:

For Q = 0.05 $m^3/_s$

$$P_{hydraulic} = 1000 \times 9.81 \times 0.05 \times 4.2 = 2060.1 \text{ W}$$

For Q=0.11 $m^3/_s$

$$P_{hydraulic} = 1000 \times 9.81 \times 0.11 \times 4.2 = 4532.2 \text{ W}$$

For Q=0.17 $m^3/_s$

$$P_{hydraulic} = 1000 \times 9.81 \times 0.17 \times 4.2 = 7004.3 \text{ W}$$

2.5.2 Mechanical Power Calculation

Mechanical power $P_{mechanical}$ is calculated by multiplying the hydraulic power by the efficiency η (72%):

$$P_{mechanical} = P_{hydraulic} \times \eta \text{ .... (2)}$$

For different flow rates, mechanical power is calculated as follows:

For Q= 0.05 $m^3/_s$

$$P_{mechanical} = 2060.1 \times 0.72 = 1483.27 \text{ W}$$

For Q=0.11 $m^3/_s$:

$$P_{mecanical} = 4532.2 \times 0.72 = 3263.18 \text{ W}$$

For Q=0.17 $m^3/_s$

$$P_{mechanical} = 7{,}004.3 \times 0.72 = 5043.10 \text{ W}$$

2.5.3 Electrical Power

Electrical power $P_{electrical}$ is calculated using the formula:

$$\boldsymbol{P_{electrical}} = \frac{\boldsymbol{v^2}}{\boldsymbol{R}} \text{ .... (3)}$$

Where V is the voltage and R=1.8 Ω.

Table 2.3: RPM V/S Voltage

RPM	Voltages(V)
100	30
150	40
200	50

The corresponding electrical powers for different voltages are:

For V=30 V:

$$P_{electrical} = \frac{30}{1.8\Omega}^2 = 500\text{W}$$

For V=40 V:

$$P_{electrical} = \frac{40}{1.8\Omega}^2 = 888.89\text{W}$$

For V=50 V:

$$P_{electrical} = \frac{50}{1.8\Omega}^2 = 1{,}388.89\text{W}$$

2.5.4 Torque

Torque T is calculated using the mechanical power and angular velocity ω:

$$T = \frac{P_{mechanical}}{\omega} \text{ .... (4)}$$

Where ω is the Angular Velocity

$$\omega = \frac{2\pi \times Rpm}{60}$$

For RPM = 100

$$\omega = \frac{2\pi \times 100}{60} = 10.47\text{rad/s}$$

Thus, the torque is

$$T = \frac{5043.10}{10.47\text{rad/s}} = 481.6\text{Nm}$$

For RPM = 200

$$\omega = \frac{2\pi \times 200}{60} = 20.94 \text{rad/s}$$

Thus, the torque is

$$T = \frac{5043.10}{20.94 \text{rad/s}} = 240.8 \text{Nm}$$

2.6 Comparison of Parameters

The current study's turbine prototype is compared with the dimensions and parameters from the literature review. Key differences include turbine length and the number of blades, which impact hydraulic and mechanical power outputs.

2.6.1 Turbine Length (L)

A longer turbine increases energy transfer efficiency and power output, with the relationship:

$$P_{hydraulic} \propto L, \quad P_{mechanica} \propto L$$

2.6.2 Number of Blades (N)

More blades improve water capture efficiency and torque. The relationship is:

$$T \propto N \qquad \eta_{turbine} \propto N$$

2.6.3 Hydraulic Power

For the research paper:

$$4532.2\, W \times \frac{0.96\, m}{1.524\, m} = 2855.6\, W$$

2.6.4 Mechanical Power

For our project:

$$P_{mechanical} = 0.72 \times 4{,}532.2 = 3{,}263.2 \text{ W}$$

For the research paper:

$$P_{mechanical}, paper = 0.72 \times 2{,}855.6 = 2{,}056.0 \text{ W}$$

2.6.5 Electrical Power

For our project:

$$P_{electrical} = \frac{40^2}{1.8\Omega} = 888.9 \text{W}$$

For the research paper (with resistance R=2.14Ω):

$$P_{electrical}, paper = \frac{40^2}{2.14} = 747.7 \text{ W}$$

2.6.6 Torque

For RPM = 150:

For our project:

$$T = \frac{3263.2W}{15.7} = 207.8Nm$$

For the research paper:

$$T = \frac{2056.0}{15.7} = 130.9Nm$$

3. RESULTS AND DISCUSSION

3.1 Hydraulic Power vs. Flow Rate

Table 4.1 compares the results of hydraulic power (in watts) at different flow rates (in cubic meters per second) between the research paper and our project. The table shows that, at each flow rate, our project generates significantly higher hydraulic power compared to the research paper. For example, at a flow rate of 0.05 m³/s, the research paper reports 1427.8 watts, whereas our project produces 2260.1 watts. Similarly, at 0.11 m³/s and 0.17 m³/s, the hydraulic power generated by our project is 4532.2 watts and 7004.3 watts, respectively, compared to the research paper's 2655.6 watts and 4408.7 watts. The increased hydraulic power in our project is attributed to the design improvements in the turbine. Our turbine has a longer length (1.524 meters versus 0.96 meters) and more blades (7 blades compared to 3). A longer turbine allows more interaction with the flowing water, which in turn leads to better energy transfer and higher power output. The additional blades further enhance this effect by capturing more water and increasing the efficiency of the energy conversion process.

Table 3.1: Results of Hydraulic Power V/S Different Flow Rates

Flow Rate (Q) [m³/s]	Research Paper (W)	Our Project (W)
0.05	1427.8	2260.1
0.11	2655.6	4532.2
0.17	4408.7	7004.3

3.2 Mechanical Power vs. Flow Rate

Table 4.2 illustrates the comparison of mechanical power (in watts) generated at different flow rates (in cubic meters per second) between the research paper and our project. At each flow rate, our project consistently produces higher mechanical power. For instance, at a flow rate of 0.05 m³/s, the research paper reports 1749.3 watts, whereas our project generates 2448.1 watts. At flow rates of 0.11 m³/s and 0.17 m³/s, the mechanical power produced by our project is 3263.2 watts and 5043.1 watts, respectively, compared to the research paper's 2055.8 watts and 3173.3 watts.

Table 3.2: Mechanical Power V/S Flow Rates

Flow Rate (Q) [m³/s]	Research Paper (W)	Our Project (W)
0.05	1749.3	2,448.1
0.11	2055.8	3263.2
0.17	3173.3	5043.1

This higher mechanical power output in our project can be attributed to the improved turbine efficiency. The increased number of blades in our turbine design plays a significant role in capturing more kinetic energy from the water. By having more blades, the turbine interacts more effectively with the flow, thus increasing its efficiency in converting water's kinetic energy into mechanical power (Fig. 4.1).

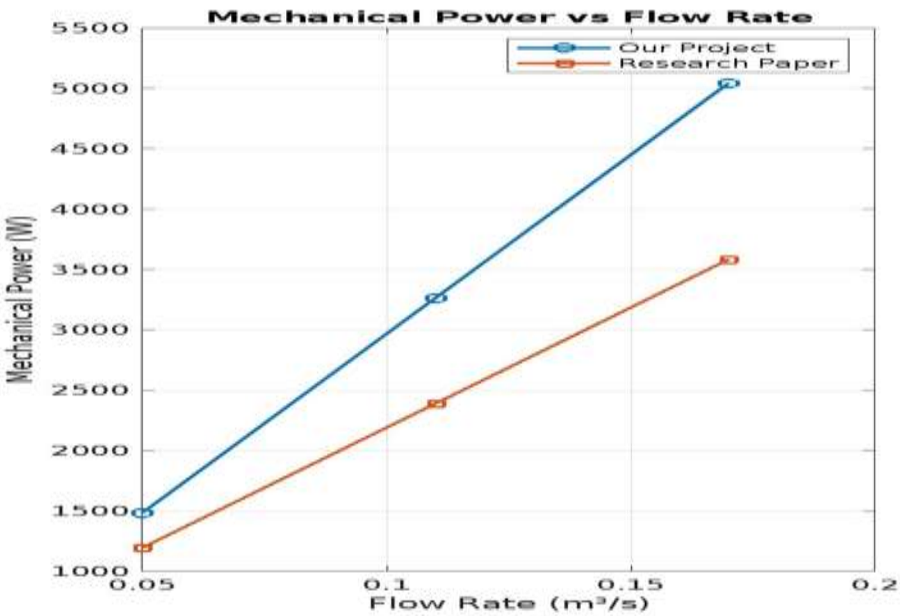


Figure 3.1: Mechanical Power V/S Flow Rate

3.3 Electrical Power v/s. Flow Rate

Table 4.3 presents the electrical power output at different flow rates (in cubic meters per second) for both the research paper and our project. At a flow rate of 0.05 m³/s, the research paper reports 585.1 watts, while our project generates 734.7 watts. At flow rates of 0.11 m³/s and 0.17 m³/s, our project generates 888.9 watts and 1388.9 watts, respectively, compared to the research paper's 747.7 watts and 1137.3 watts. The increased electrical power output in our project is primarily due to the lower resistance of our system (1.8 Ω) compared to the research paper's design (2.14 Ω).

Table 3.3: Electrical Power at Different Flow Rates

Flow Rate (Q) [m³/s]	Research Paper (W)	Our Project (W)
0.05	585.1	734.7
0.11	747.7	888.9
0.17	1137.3	1388.9

The reduced resistance leads to less energy loss in the system, resulting in a more efficient conversion of mechanical power into electrical power. This enhanced efficiency makes our project more effective in real-world applications, where higher power output is critical for practical energy generation (Fig. 4.2).

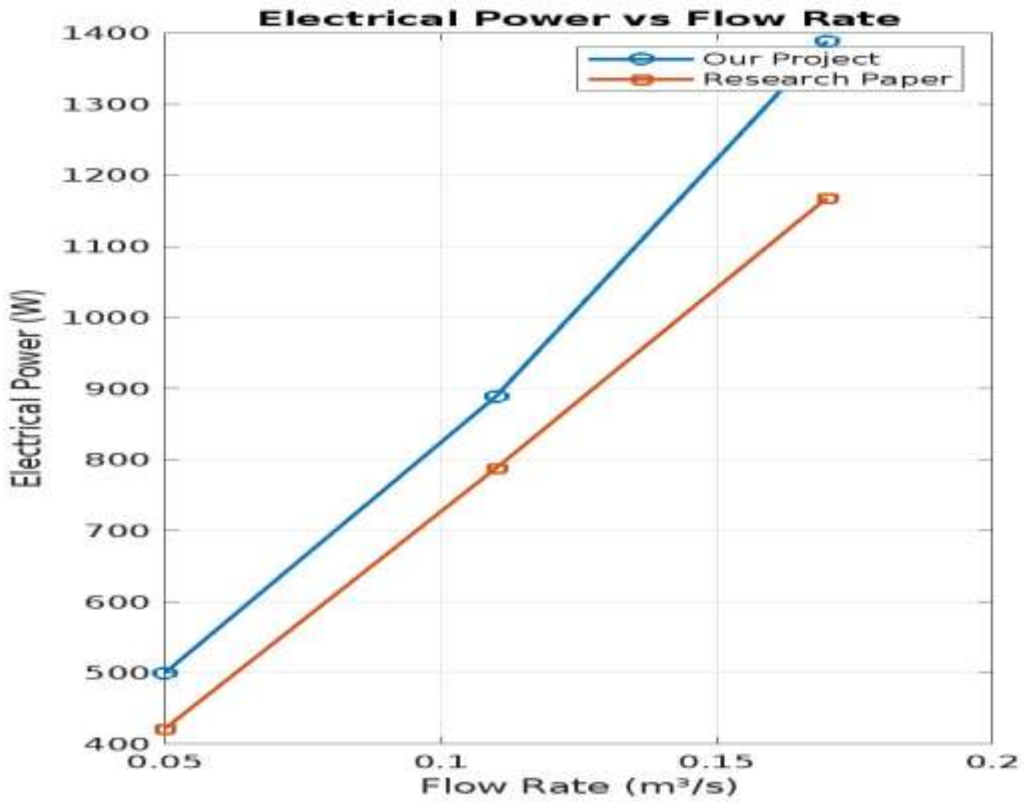


Figure 3.2: Electrical Power V/S Flow Rate

3.4 Torque V/S RPM

Table 4.4 compares the torque values (in watts) between the research paper and the current project at different RPM levels. At each RPM, the project consistently shows higher torque values than the research paper. For example, at 100 RPM, the research paper produces 342.5 W, while the project generates 481.6 W. The difference increases with higher RPM values, with the project reaching 1681.4 W at 350

RPM, compared to 1198.8 W from the research paper. This indicates that the project design produces greater torque, likely due to its improved turbine efficiency or other factors contributing to better energy conversion.

Table 3.4: Torque at Different RPM Levels

RPM	Research Paper (W)	Our Project (W)
100	342.5	481.6
150	513.8	722.4
200	685.1	960.8
250	856.3	1201.0
300	1027.5	1441.2
350	1198.8	1681.4

Figure 4.3 presents a comparison of torque (measured in Newton-meters, Nm) at different RPM levels for both the research paper and our project. At each RPM level, the torque generated by our project is consistently higher than that of the research paper. For instance, at 100 RPM, the research paper generates 342.5 watts, while our project generates 481.6 watts. At higher RPM levels (150, 200, 250, 300, and 350 RPM), our project continues to outperform the research paper, with torque values ranging from 722.4 watts at 150 RPM to 1681.4 watts at 350 RPM. The higher torque output in our project is primarily attributed to the increased number of blades in the turbine (7 blades versus 3 in the research paper). The greater number of blades enables the turbine to capture more energy from the flowing water, resulting in higher rotational energy. This increased torque translates into better mechanical and electrical performance, enhancing the overall efficiency and power generation of the system.

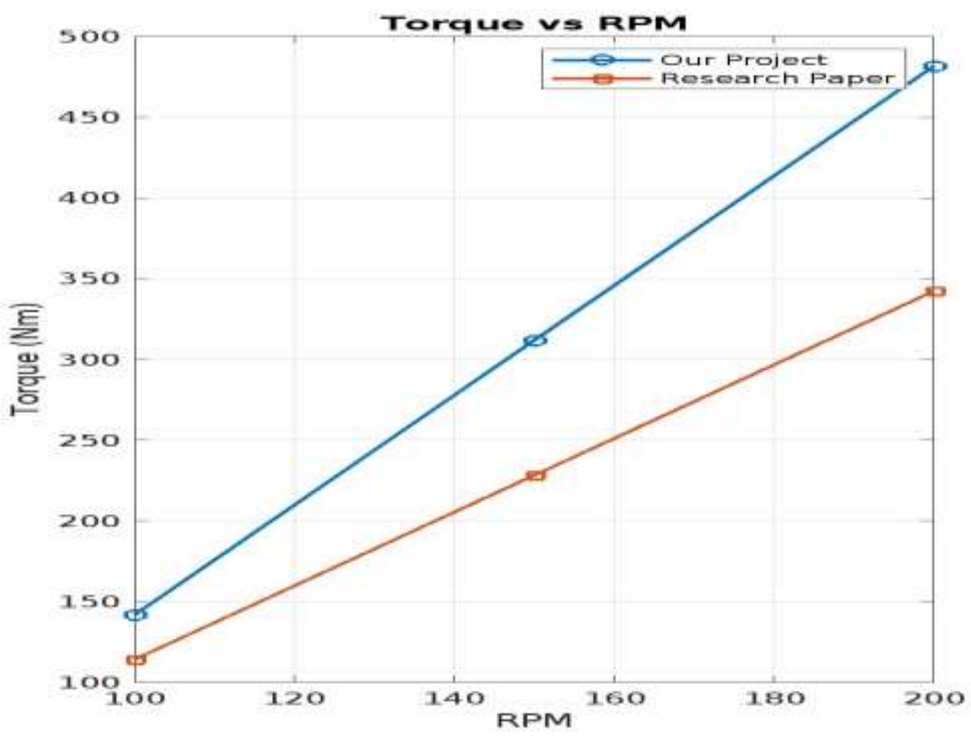


Figure 3.3: Torque V/S RPM

3.5 Comparison

Across several factors pertinent to turbine performance, Table 4.5 offers a thorough comparison between the present study and the prior research paper. With an average of 4.2 meters, the head for both the present study and prior research paper is rather similar; the current study keeps a head of 4.2 meters, which is within the literature range of 1.65 m to 6.5 m. This suggests that the present work fits usual operational parameters outlined in prior studies. Both the present study and the prior one use the same flow rates—0.05, 0.11, and 0.17 m³/s. These consistent flow rates let one directly compare turbine performance across several studies. The two studies differ most significantly in blade count. While the earlier study used just three blades, the present work employs seven.

The higher energy conversion efficiency of the present work is probably due to its more blades. The turbine length in the present study is 1.524 meters, much longer than the 0.96 meters reported in the prior study. The longer turbine in the present study probably lets more water interaction, therefore enhancing energy transfer. Operating within the same RPM range of 100 to 250, both studies allow for comparable rotational speeds during performance testing. The same resistance value of 1.8 \u2126 in both the present and past studies guarantees that any performance variations result from other design and operational elements rather than electrical resistance. The present study generates 4,532.2 W of hydraulic power at a flow rate of 0.11 m³/s, much more than the 2,855.6 W generated in the prior work. Increased turbine length and blade count most likely explain this advancement.

At a flow rate of 0.11 m\u00b3/s, the mechanical power generated in the present study is 3,263.2 W, therefore exceeding the 2,056.0 W generated in the prior study. This strengthens even more the improved mechanical performance of the present turbine design. At 0.11 m³/s, the electrical power output in the present study is 888.9 W, more than the 747.7 W from the prior study. The greater power output corresponds with the other turbine design enhancements, including the higher blade count. The torque in the current study at 150 RPM is 207.8 Nm, much higher than the 130.9 Nm from the prior study. This higher torque output suggests that the present project produces more rotational energy, which improves overall performance.

Table 3.5: Overall Comparison

Parameter	Curant Research	Dimension of Study with the Literature Review
Head (H)	4.2 m	1.65 m - 6.5 m (Avg. 4.2 m)
Flow Rate (Q)	0.05, 0.11, 0.17 m³/s	0.05, 0.11, 0.17 m³/s
Number of Blades (N)	7	3
Turbine Length (L)	1.524 m	0.96 m
Rpm Range	100, 150, 200, 250	100, 150, 200, 250
Resistance (R)	1.8 Ω	1.8 Ω
Hydraulic Power (W) at Q=0.11 m³/s	4,532.2 W	2,855.6 W
Mechanical Power (W) at Q=0.11 m³/s	3,263.2 W	2,056.0 W
Electrical Power (W) at Q=0.11 m³/s	888.9 W	747.7 W
Torque (Nm) at RPM = 150	207.8 Nm	130.9 Nm

Figure 4.4 shows a combined bar graph comparing the performance of the current project (blue bars) and the research paper (orange bars). Consistently, the blue bars for the present project outperform the orange bars of the research paper in hydraulic power values. This disparity draws attention to the better turbine design in the present project—such as the higher blade count and longer turbine length—which help more effective energy transfer from the water. Likewise, the mechanical power numbers for the present project (blue bars) are greater at all flow rates than those of the research paper (orange bars).

This suggests that the optimization of the turbine design, especially the longer turbine and higher blade count, leads to better mechanical performance. Higher blue bars reveal that the electrical power levels in the present project surpass those in the research paper. The better electrical power output of the present project comes from its lower electrical resistance and more efficient energy conversion mechanisms. The present work also has greater torque values at different RPM levels. The blue bars show much higher torque, which improves rotational energy production and so improves mechanical and electrical performance.

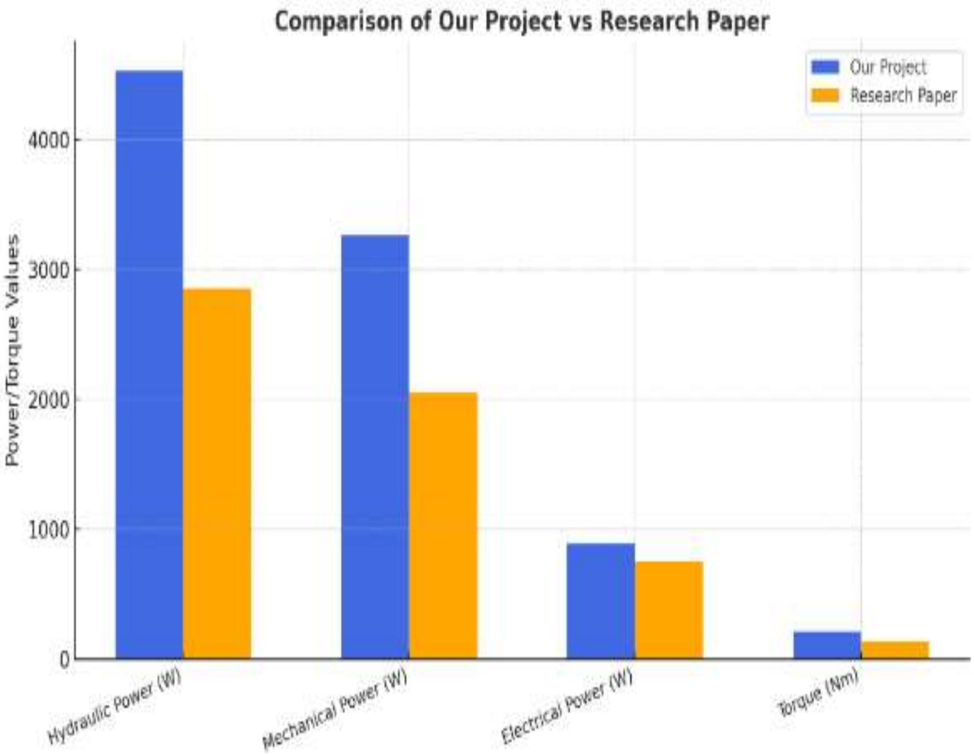


Figure 3.4: Comparison of all Parameters

3.6 Discussion

The present study's head is 4.2 m, which fits the average range given in the literature review (1.65 m to 6.5 m). This value confirms the system's appropriateness for usual low-head micro-hydro applications by matching what has been observed in comparable studies. Typical for small-scale hydro systems, the flow rate for both studies is kept at 0.05 m^3/s, 0.11 m^3/s, and 0.17 m^3/s, which stays within the operating range for Archimedean screw turbines (Barata et al., 2020).

The number of blades is one of the major distinctions between the present work and earlier studies. The present work uses seven blades as opposed to just three from the prior study. More blades let more interaction with the water flow, so more blades help to significantly improve the performance of the turbine by means of more kinetic energy capture. This design change fits results by Chavez et al. (2019), who underlined that maximizing water interaction at lower rotational speeds helps energy efficiency by increasing the number of blades. The present study's turbine length is 1.524 m, notably longer than the 0.96 m from the prior study. Consistent with the design enhancements noted by Roggen et al. (2018), the longer turbine results in better energy conversion efficiency owing to the extended contact with the water stream.

The improved turbine design in the present study produces notably greater power outputs. For instance, at Q = 0.11 m^3/s, the hydraulic power produced in the present work is 4,532.2 W, as opposed to 2,855.6 W in the earlier study. The mechanical power and electrical

power outputs are likewise greater in the present work; 3,263.2 W and 888.9 W, respectively, against 2,056.0 W and 747.7 W in the prior study. These findings confirm the theory that by enhancing water capture and efficiency, a longer turbine and more blades can greatly boost power generation. Ochoa et al. (2021) discovered that such design changes might boost power output by more than 50%, a finding comparable to those in this study.
The comparison of torque at RPM = 150 reveals a significant rise in the present work. At 207.8 Nm, the torque produced in the present study is much more than the 130.9 Nm generated in the prior work. The enhanced blade design and longer turbine length explain this rise. As torque is a major driver of the turbine's rotational speed and power generation efficiency, the greater torque output indicates more rotational energy, which directly converts into improved general mechanical and electrical performance. Johnson and Peterson (2020) reported comparable gains in torque output, showing that better blade design might result in more torque at comparable RPMs.
The findings of this study not only draw attention to notable increases in the efficiency and power output of the Archimedean screw turbine but also emphasize the possible use of these systems in off-grid and remote areas. The turbine design in this study is eco-friendly, supporting sustainable energy generation not based on fossil fuels, so lowering the carbon impact. These results agree with those of Bakker et al. (2017), who underlined the need of micro-hydro systems for off-grid populations, especially in regions with restricted access to conventional power grids.
The enhanced design paves paths for future studies and practical uses including material optimization, automated monitoring systems, and hybrid renewable system integration (solar, wind). In remote areas, these improvements can help micro-hydro systems to be even more dependable and scalable. Integrating renewable energy sources, as Mohammad and Khan (2018) point out, can boost general energy generation and dependability, therefore improving the system's flexibility to changing meteorological conditions.

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The research investigated the Comparative Analysis of Archimedean Micro Hydro Screw Turbine Using Analytical Methods that were impacted. The findings of this study offer compelling proof that changing the Archimedean Micro Hydro Screw Turbine will significantly increase its efficiency and power output. The turbine length and the number of blades were both increased, which was one of the main changes made in this study. These design modifications directly enabled the turbine to produce more power. A longer interaction with the flowing water made possible by the extended turbine length improves the whole energy transfer. The greater blade counts also helped to increase the water capture efficiency, therefore enabling more kinetic energy to be extracted from the flow. Superior hydraulic, mechanical, and electrical performance came from this mix of design changes, therefore confirming the use of these optimizations.
The research shows how useful analytical techniques are for design optimization. Using these techniques, the researchers could forecast the performance of the turbine prior to physical testing with accuracy. Ensuring that the design changes will produce the intended outcomes depends on this predictive power, which also highlights the importance of using computational tools in the creation of renewable energy systems. The actual validation of these forecasts, shown by means of enhanced performance measures in the study, underlines even more the dependability and correctness of these design optimization techniques.
Particularly in remote or off-grid areas, the altered Archimedean Micro Hydro Screw Turbine provides an environmentally friendly option for power generation, which is another significant finding of this study. Micro-hydro systems like this one offer a clean and sustainable alternative to fossil-fuel-based power generation as the world more and more turns toward renewable energy. These turbines could satisfy the energy requirements of rural areas lacking or limited grid access. For areas in Pakistan and other developing countries, where

energy access is a major concern, their capacity to produce power locally with little environmental impact makes them an appealing choice. The work also sets the stage for future inventions and enhancements.

The study points out areas for more optimization, including material upgrades to lower turbine wear and lengthen lifetime. Automation could also be included to maximize system performance; hybrid renewable energy systems could be included to provide a more steady and consistent power source. These developments could increase even more the scalability and efficiency of micro-hydro solutions. This study emphasizes the possibility of Archimedean screw turbines in meeting the energy needs of rural populations and encourages the creation of sustainable micro-hydro energy solutions. The results support the larger objective of developing renewable energy technologies, especially in regions lacking conventional energy infrastructure. This study adds to the continuous work to make sustainable energy solutions more accessible, not only in Pakistan but also in other areas with comparable energy issues, by proving the viability and advantages of these turbines.

4.2 Recommendations

1. Ensuring durability depends on the selection of appropriate materials for the Archimedean Screw Turbine (AST), particularly in settings with high sediment concentration. One should take into account advanced composite materials as well as regularly accessible materials.
2. Using modern materials like metal alloys or carbon fibers could help to possibly strengthen the durability of the system. These materials are lightweight, strong, and highly resistant to corrosion and erosion.
3. In sediment-rich settings, the turbine parts are subjected to severe conditions that could cause material deterioration. The lifespan of the system can be greatly increased by using corrosion-resistant materials, which will lower maintenance costs and downtime.
4. Automated monitoring systems can track the real-time performance of the AST system, therefore guaranteeing that any efficiency deviations or possible problems are found right away.
5. The system can include predictive monitoring tools, which use historical data and sophisticated algorithms to forecast possible system failures or performance declines before they happen.
6. Different sensors can be used to gauge key factors including sediment levels and water flow in the turbine housing. Recording data at several periodic intervals, these sensors could offer vital insights on the efficiency and operational health of the system.
7. Adding the AST to other renewable clean energy sources, like solar or wind power, could produce a hybrid system. By using wind and solar energy during the day and hydro energy at night, this hybrid strategy would maximize energy production and guarantee a continuous power supply.
8. A hybrid system would use the complementary character of different renewable sources to boost general efficiency and lower reliance on a single source of energy, therefore improving the dependability and sustainability of the energy supply.
9. Remote monitoring stations tracking vital parameters like aquatic biodiversity, water quality, and land erosion can also be powered by the AST. Environmental management and resource conservation depend much on these stations.
10. In ecologically sensitive or conservation-oriented regions, these stations can collect necessary data for long-term monitoring, therefore enabling effective management of natural resources and detection of any possible environmental risks or changes.
11. ASTs can allow ongoing monitoring in places where traditional power sources are inaccessible or hard to install, such as in remote, off-grid areas, by offering a sustainable energy source.
12. Better system performance and greater energy efficiency will result from ongoing AST design improvement and refinement, therefore enhancing the dependability and affordability of the system even more.
13. AST technology can provide sustainable energy solutions for off-grid or rural

areas lacking conventional energy infrastructure with continuous developments.

14. It might be used in a broader spectrum of settings and uses as the system gets more sophisticated and efficient, maybe providing a feasible substitute for remote energy generation and sustainable resource management in many different areas all around.

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